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Nonlinear rheology of soft glassy materials

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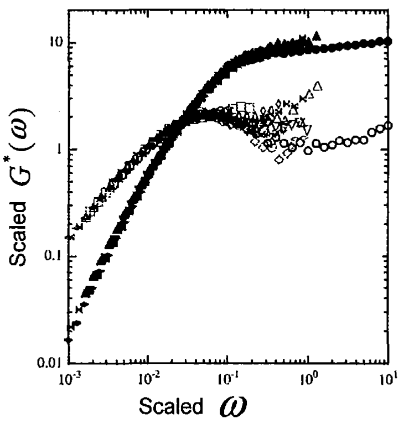
コロイド分散系やペーストなど、いわゆる「やわらかいガラス」において観測される、普遍的な非線形レオロジーを記述する微視的理論の紹介と、新しいレオロジー実験の提案を行う。

Many soft glassy materials such as dense colloidal suspensions, pastes, and particle gels show an universal nonlinear viscoelasticity with increasing oscillatory-strain amplitude. It has been known for long time that, for fixed frequencies, the storage modulus $G'(\omega)$ decreases monotonically as the strain amplitude γ increases whereas the loss modulus $G''(\omega)$ has a distinct peak around $\gamma \approx 1$ followed by decrease at larger strains. This ubiquitous behavior can be understood by noticing that the characteristic relaxation time of many glassy systems are extremely sensitive to the strain rates. Under shear flow, the structural relaxation time is roughly given by $\tau^{-1} = \tau_0^{-1} + \dot{\gamma}$, where $\dot{\gamma}$ is the strain rate and τ_0 is the relaxation time without shear[1]. The peak of $G^*(\omega)$ should be observed around $\omega \approx 1/\tau$, this means that peak is at $\omega \approx \tau_0^{-1} + \dot{\gamma} \approx \omega\gamma$. Therefore, if the frequency is fixed, the peak should appear around $\gamma \approx 1$. In order to confirm this simple argument, we have generalized the mode coupling theory (MCT) for glassy systems to those under oscillatory shear flow[2]. We show that the peak should be observed in the β-relaxation frequency regime and at $\gamma \approx 1$. The argument leads to an approximate but universal principle to be hold for SGMs, which we call the Strain-Rate Frequency Superposition (SRFS)[2]; an analogue of the celebrated time-temperature superposition. SRFS makes it possible to infer the structural relaxation times which are often difficult to access by standard linear rheology measurement.



SRFS maps $G^*(\omega)$ measured at different strain rates onto a single curves[2].

This work was carried out in collaboration with H. M. Wyss, D. A. Weitz, D. R. Reichman, and R. Yamamoto.

References

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